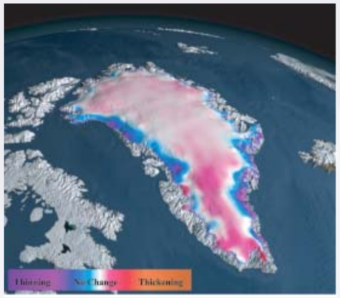
The 11th International Circumpolar Remote Sensing Symposium
September 20-24, 2010,Cambridge, United Kingdom

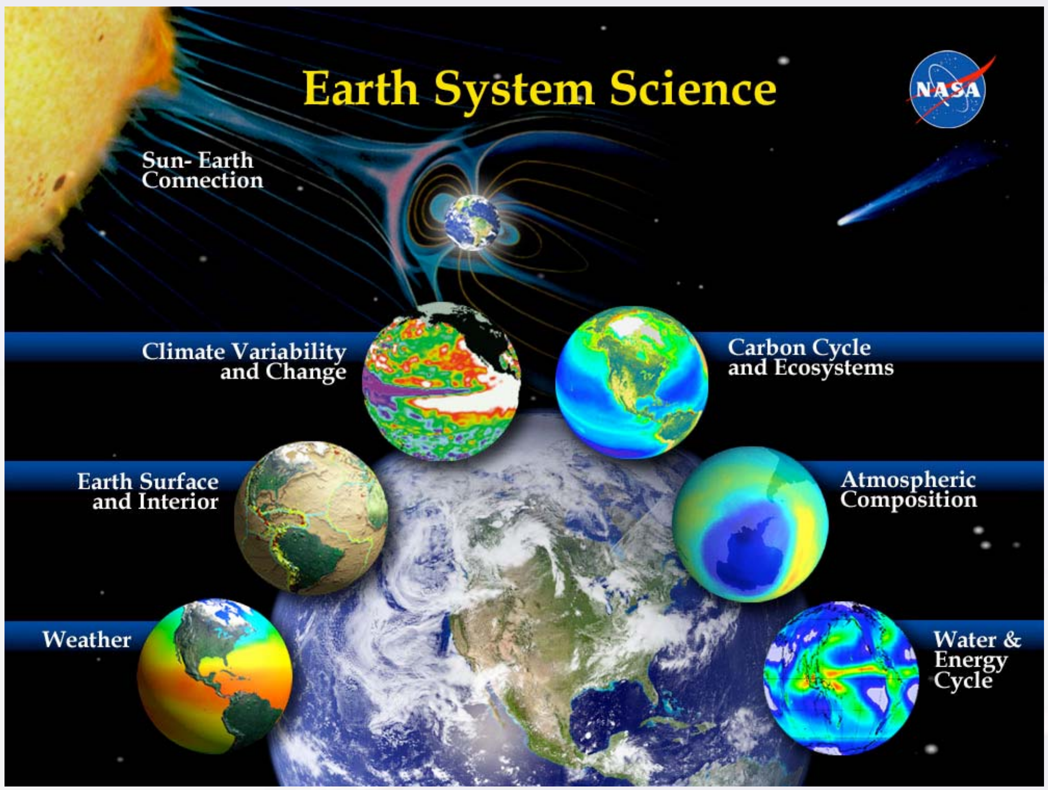
NASA Airborne Science Program—IPY missions demonstrating remote sensing technologies for unmanned aircraft in the Arctic



Susan Schoenung
Bay Area Environmental Research Institute,
NASA Ames Research Center
Randy Albertson
NASA Dryden Flight Research Center

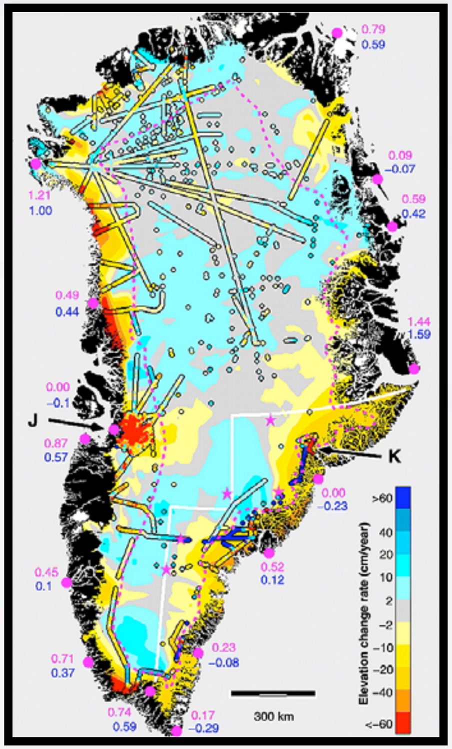
Outline

- NASA’s Earth Science and Airborne Science Programs
- Unmanned Aircraft Systems (UAS) Projects for the International Polar Year
- NASA Operation Ice Bridge missions in the Arctic and Antarctic



Program Motivation

- •NASA’s Earth Science and Airborne Science Programs support research in the Arctic and Antarctic
- UAS have both advantages and challenges at the poles
- Recent and ongoing missions demonstrate these capabilities



UAS requirements	Values
Endurance, range	24+ hours, up to 8,000 nmi
Payload capability	Remote sensing, in situ, meteorology
Satcom capability	Over-the-horizon at High latitudes, need bandwidth
Altitude - low Altitude - high	<500 to 2000 feet 60,000 to 70,000 feet
Environmental conditions	Harsh: cold, wind, dark
Air space regulations	Domestic (FAA) and International

Airborne Science Program Support for International Polar Year UAS Missions

- **5 UAS-related Instrument Projects Selected**
- Ice surface roughness
- Ice thickness
- Glacier changes
- Arctic clouds
- Polar atmospheric measurements

PI	Instrument	Platform	Mission location	Mission Schedule
Maslanik, CU	Ice profilometer	SIERRA	Svalbard, NO	June 09
Moller, JPL	Ka-band SAR	G-III (UAS surrogate)	Greenland	May 09
Zebker, Stanford	L-band SAR	G-III (UAS surrogate)	Greenland	May 09
McGill, GSFC	Cloud Physics Lidar	Global Hawk	Alaska, Arctic	March- April 2010
Mahoney, JPL	Microwave Temperature Profiler	Global Hawk	Alaska, Arctic	March-April 2010

Sea Ice Roughness Experiment

PI team
- Jim Maslanik, University of Colorado
- Mike Gaunce, Mark Sumich, Matt Fladeland NASA Ames

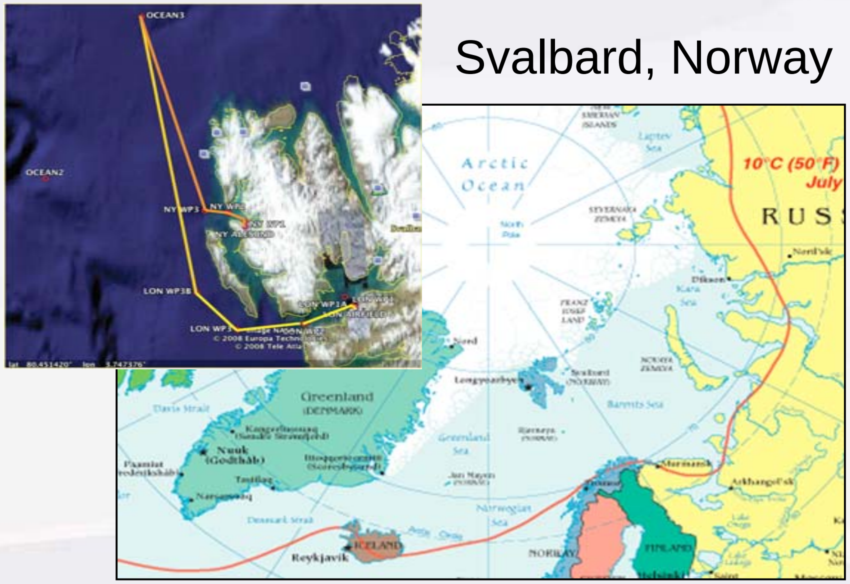
Mission
"Characterization of Arctic Sea Ice Experiment"

Specifications
- •Wingspan: 20 ft
- •Length: 11.8 ft
- •Height: 4.6 ft
- •Flight duration: 8-10 hrs
- •Range: 600 mi
- •Useful payload: up to 100 lb
- •Max altitude: 12,000 ft
- •Air speed: 50-80 knots

SIERRA UAS

Instruments
2 Laser Profilometers
MicroSAR
Microspectrometer
2 Tracking Cameras

Svalbard, Norway

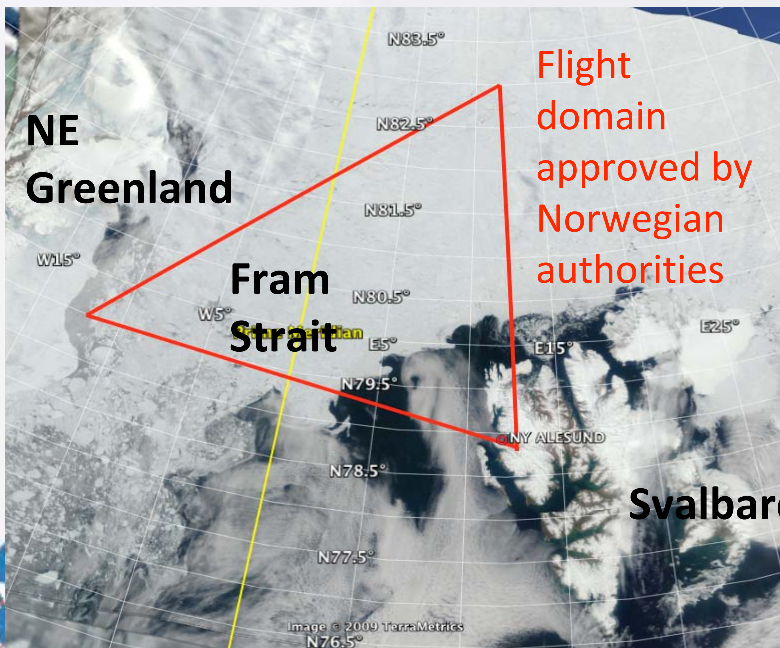


Characterization of Arctic Sea Ice Experiment (CASIE)

Research Goal: Quantify how recent changes in Arctic sea ice affect total ice volume and ice characteristics: "Do we understand the changes and how they affect future of the Arctic?"

CASIE Objectives: Unmanned aircraft systems missions (July 2009) to acquire high-resolution, multisensor data over a variety of multiyear ice conditions and types, taking advantage of the Ny-Alesund, Svalbard research base to access the Fram Strait ice cover

Approach: Low-altitude, long-range UAS flights with a combination of airborne sensors, coincident with satellite overpasses



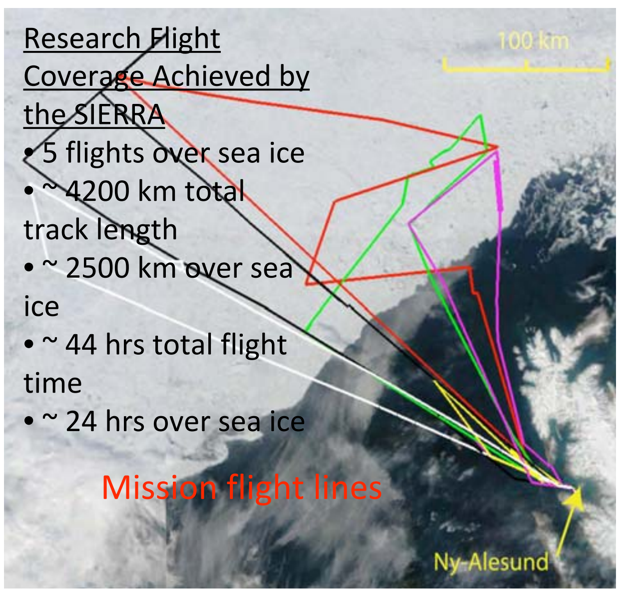
NASA Ames Research Center's SIERRA UAV at Ny-Alesund, Svalbard

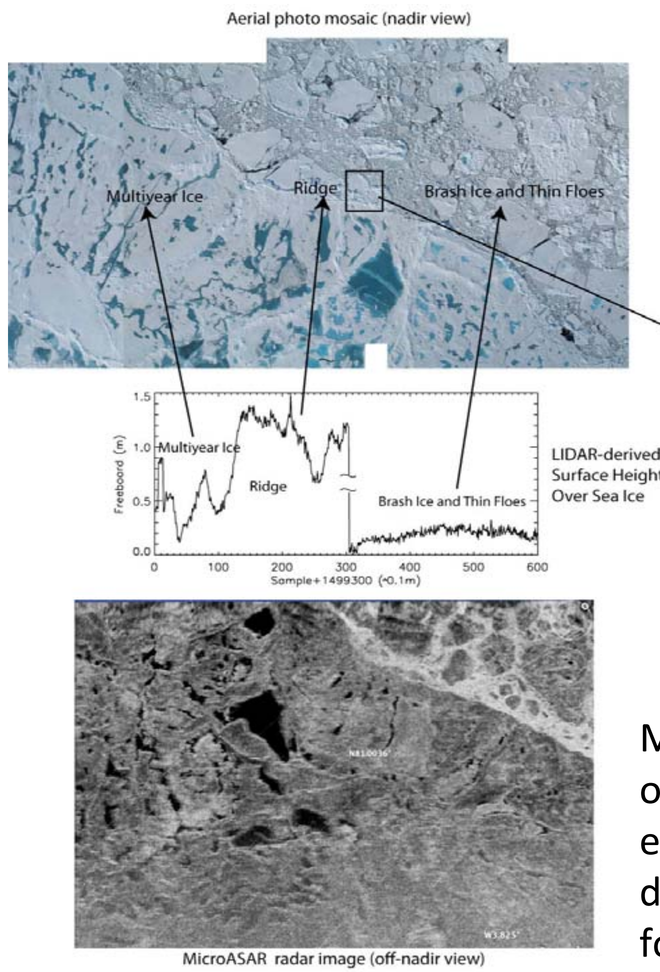
J.A. Maslanik[1], R.I. Crocker[1], K. Wegrzyn[1], C. Fowler[1], U. Herzfeld[1], D. Long[3], R. Kwok[4], M. Fladeland[2], G. Bland[5], P. Bui[2]; [1] Aerospace Engineering Sciences, University of Colorado, Boulder, [2] Ames Research Center, NASA, [3] Brigham Young University, [4] Jet Propulsion Laboratory, NASA, [5]GSFC/Wallops Flight Facility, NAS

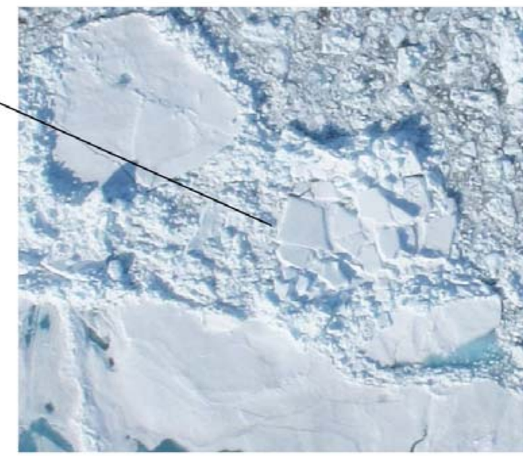
Key Results to Date: Aircraft data confirm existence of distinct sea ice categories that will assist in (1) assessing contributions of ice ridging to total sea ice volume, (2) quantifying overall significance of recent large-scale changes in ice, and (3) evaluating treatments of sea ice in climate models

Example Data: Combinations of LIDAR profiling, optical imagery and radar imagery provide unique, highly detailed ice information revealing relationships between ice conditions and ice types.

Data Volume: 920 Gb from SIERRA sensors (lidar, synthetic aperture radar, cameras)

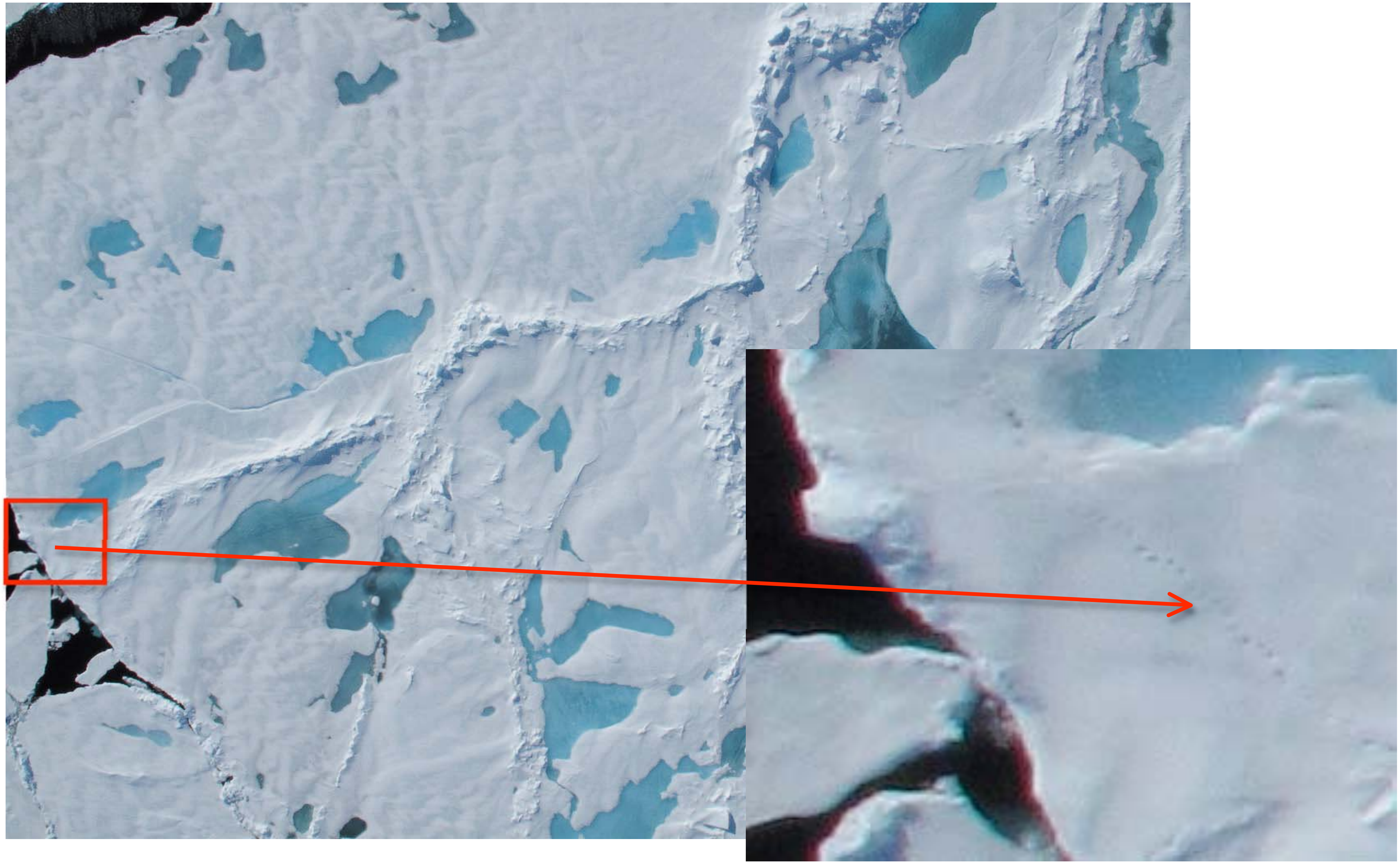




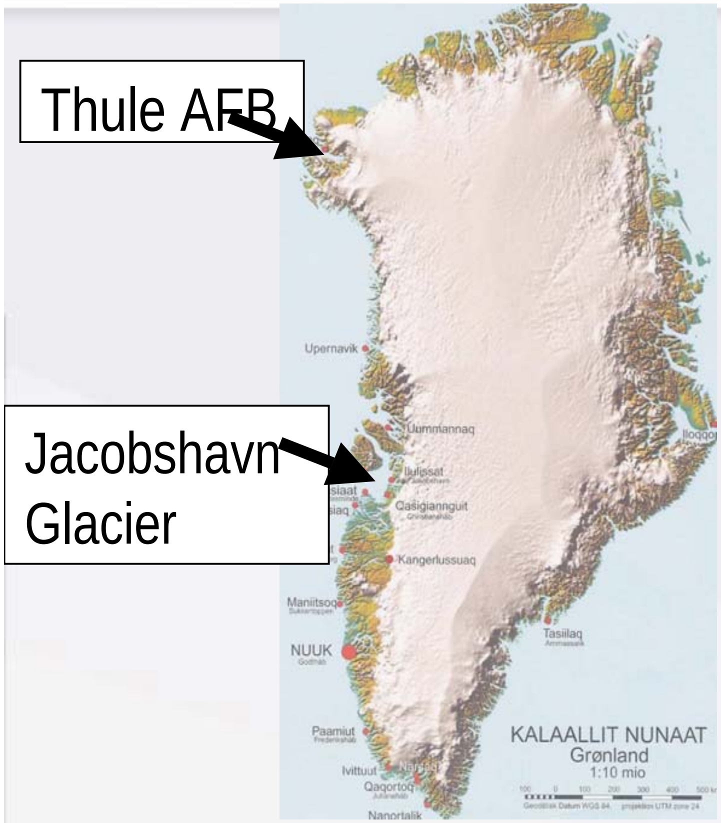


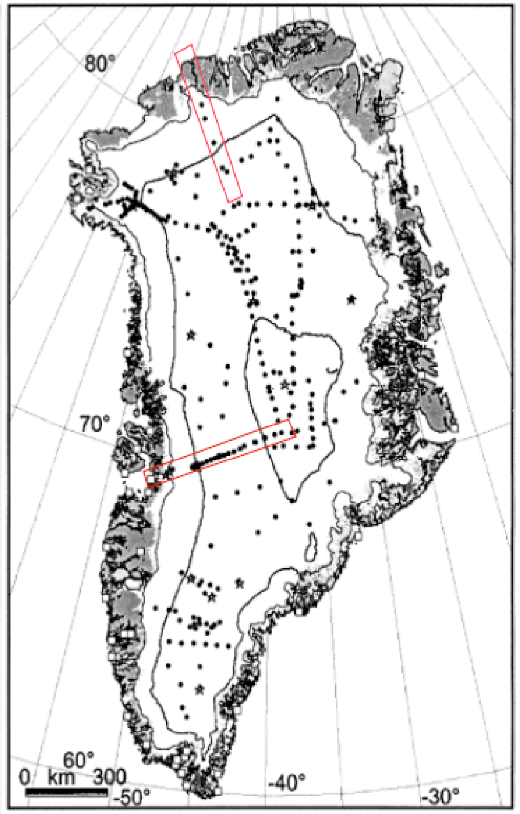
Merged lidar, radar, and optical imagery showing extremes in ice roughness and differences in surface albedo for different ice types

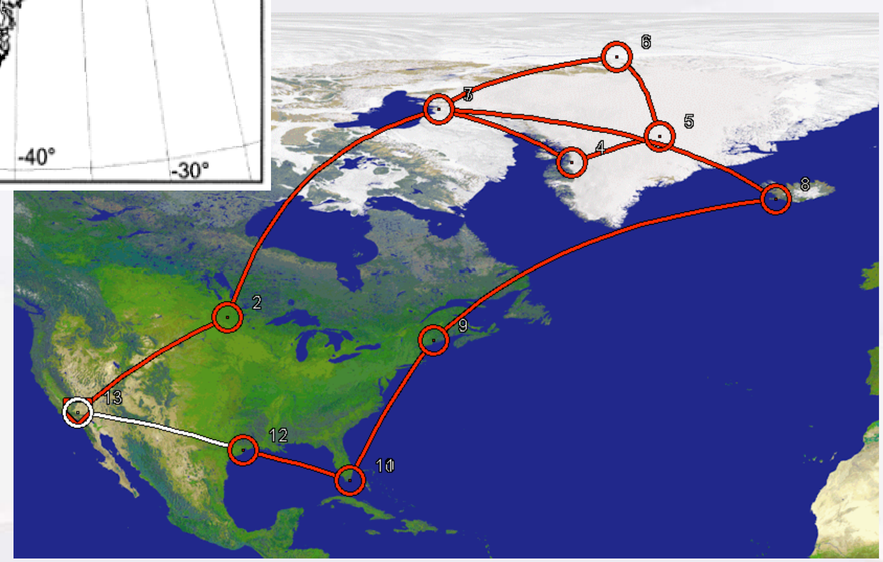
CASIE photograph acquired from 500 ft. altitude, showing meltponds and ridges on multiyear ice (inset: polar bear tracks)



Greenland Locations for UAV-SAR Experiments







Microwave INSAR Properties of the Polar Ice Sheets

PI team

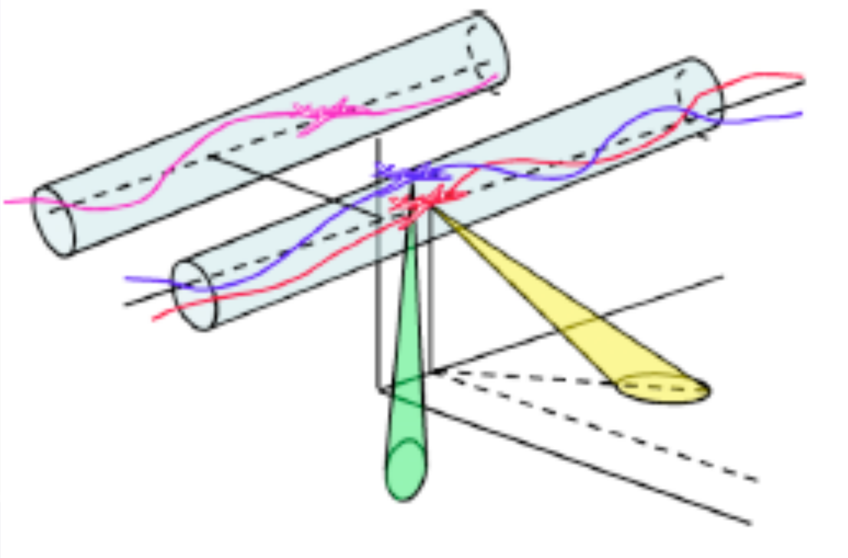
- Howard Zebker, Stanford University
- Scott Hensley, JPL

G-III with SAR and precision autopilot

Instrument / Mission

- Make use of new airborne, repeat-pass polarimetric SAR capability for flight on a UAV or Aircraft
- Develop a polarimetric, electronically scanned L-band array and associated radar system that will fit into an easily deployed and stowed radar instrument pod.

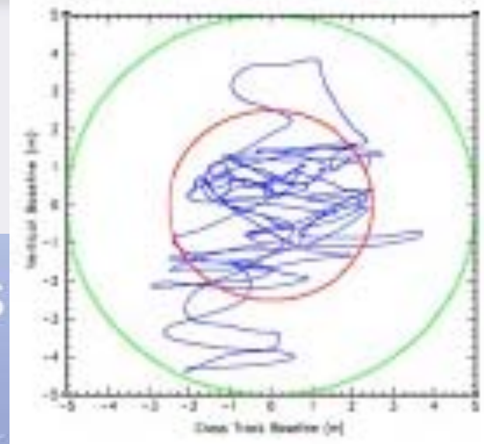
Repeat-Pass Interferometry

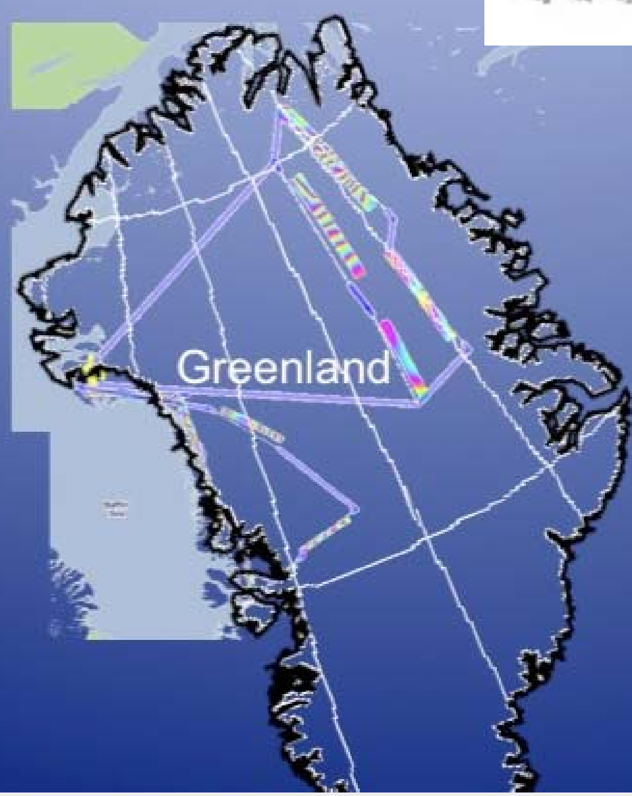


UAVSAR - Greenland

		est		actual
9G009	Moller/Zebker	120	IPY	103.1
9G026	Jones	0	Waves	0
9G027	Simons	30	Iceland	31.0
9G028	Rignot	15	Coast Grnlnd	15
9G029	Moller	2	SWOT	2
9G015	Simard	2	Everglades	2
9G022	Blom	10	Gulf Coast	10
9G006	Anastoos	1	Miss Levees	1
total		180		164.1

UAVSAR acquisitions





Cover similar conditions to those in ALOS tracks

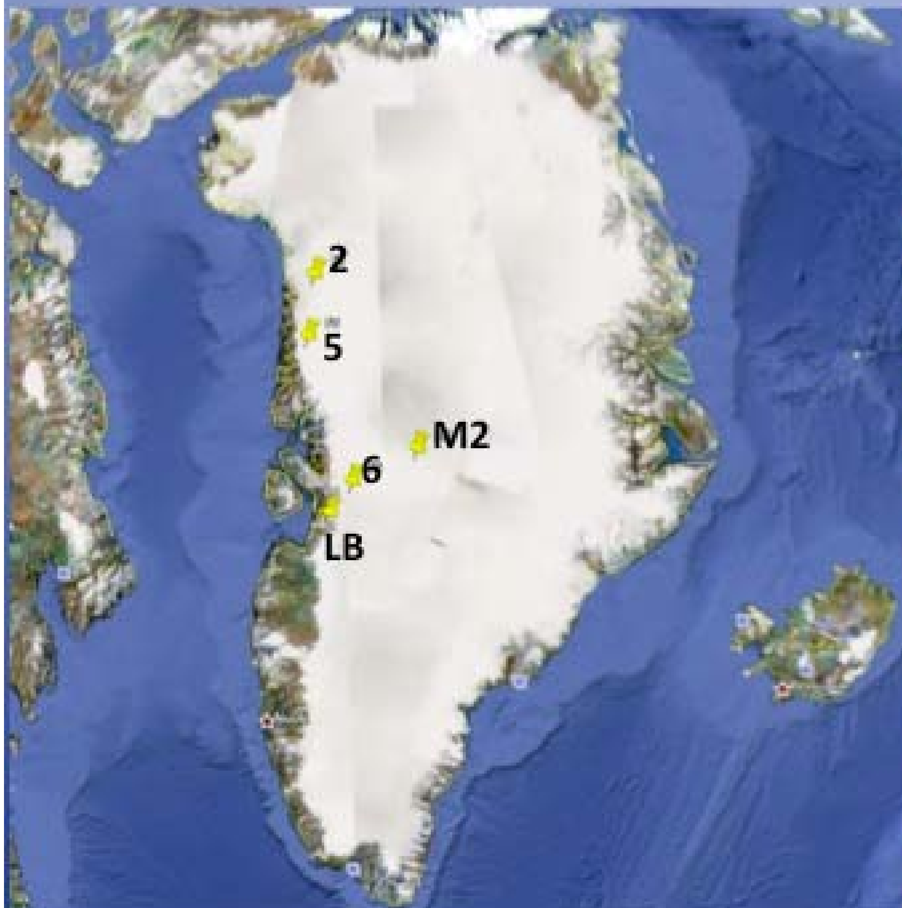
UAVSAR - L-band Mission

Sample UAVSAR Greenland Data

- Repeat-pass tracks about 52 km in length from the west coast of Greenland just north of Jakobshavn Glacier
- Temporal baseline 1.007 days
- Scene consists of primarily of ice, with increasing in elevation of 800 m from the coast to the interior part of the track

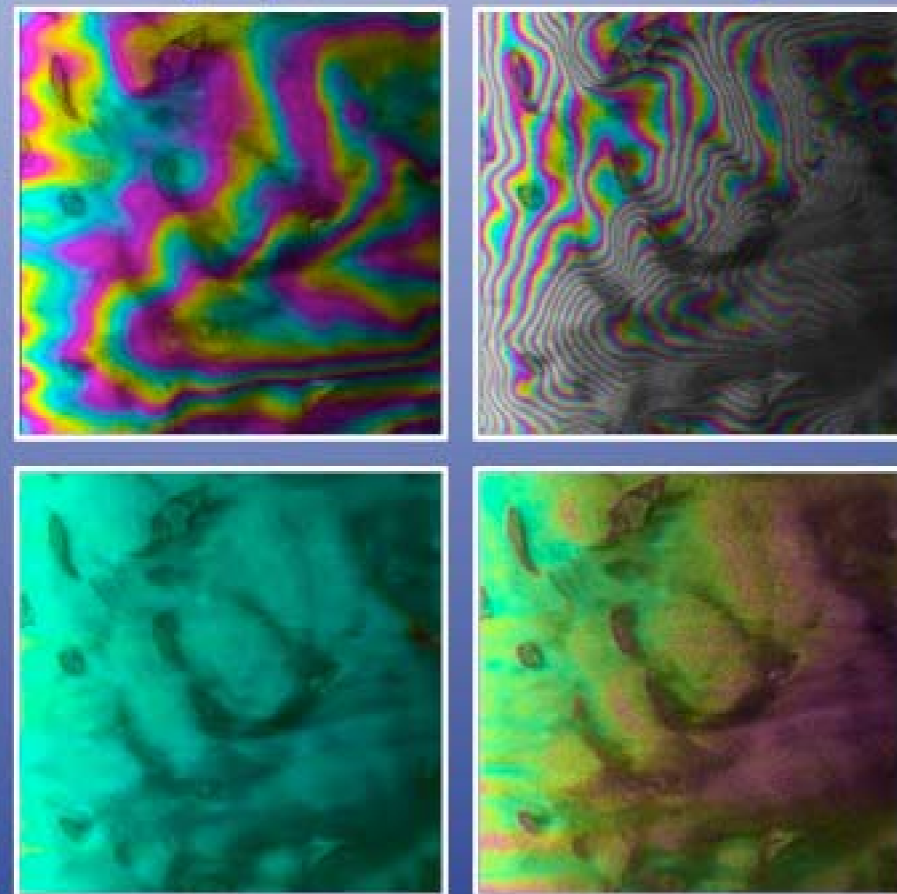
Parameter	Track 1	Track 2
Date Collected	5/26/2009	5/2
Yaw (deg)	-0.5°	-0.4°
Pitch (deg)	2.0°	2.2°
Steering Angle	-0.8°	-1.0°
Altitude	12.5 km	12.5 km

UAVSAR - Processed data to date



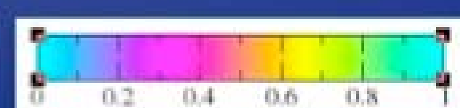
Location 2

1 Day Repeat **1 Week Repeat**



Correlation Mean: 0.91 Correlation Mean: 0.6

Correlation



An Interferometric Ka-band Synthetic Aperture Radar: A New Technique for Glacier and Ice-sheet Topography Mapping

International Polar Year:

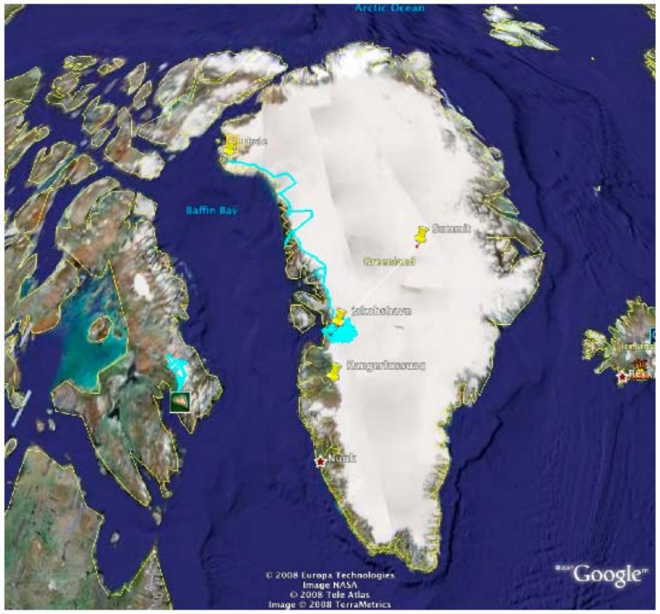
As an outcome of the GLISTIN IIP the NASA International Polar Year funded a Ka-band single-pass interferometer utilizing UAVSAR to enable demonstration of the measurement phenomenology.

- Will characterize the penetration depth of Ka-band into snow cover as a function of snow wetness and incidence angle.
- Critical to the feasibility of a future radar ice surface topography mapping mission.
- Implementation highly leverages borrowed hardware (PR2) and UAVSAR infrastructure, in addition to antennas derived from the IIP design.
- Deployment to Greenland Spring ‘09 in collaboration with other Bill Krabill (ATM) and Koni Steffen (CIRES)

PI: Delwyn Moller - Remote Sensing solutions
Co-Investigators: Scott Hensley, Greg Sadowy, Eric Rignot, Marc Simard, JPL

First known demonstration of millimeter-wave single-pass interferometry:

Relevant not only for Earth ice-surface topography, but also for surface water, ocean surface topography and interplanetary (e.g. Europa) ice cover measurements



Nominal flight locations staging out of Thule. Primary target is Jakobshavn Glacier with an additional transect to Summit. Coincident data will be collected by the ATM sensor on the P3

REMOTE SENSING SOLUTIONS

A Ka-band Interferometer for Ice Surface Topography

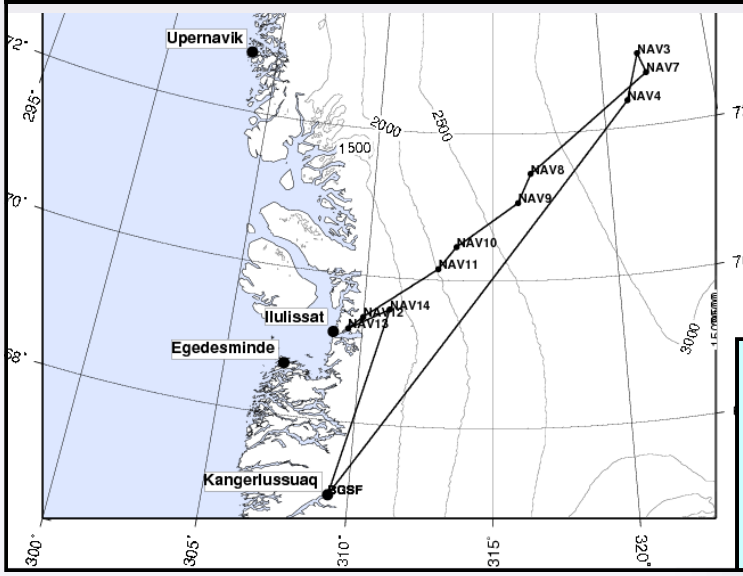
Ka-band antennas installed on the NASA GIII configured for single-pass interferometry

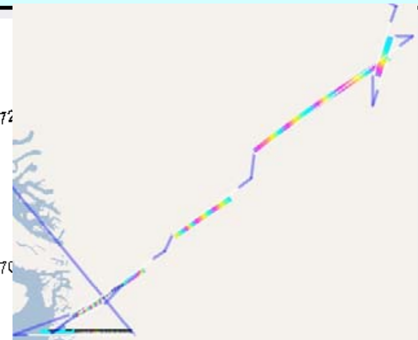
System Implementation:

- Adapt the JPL UAVSAR system to operate in a single-pass interferometric mode:
  - A Ka-band upconverter/downconverter chain is added to the L-band (borrowing PR2 hardware)
  - The two polarimetric channels of UAVSAR are used for the two interferometric channels
  - The L-band antenna panel is replaced with two 0.5m slotted waveguide antennas (design derived from the IIP).
  - The UAVSAR data-acquisition system and processing infrastructure is already capable for this application

GLISTIN Greenland Campaign Summary

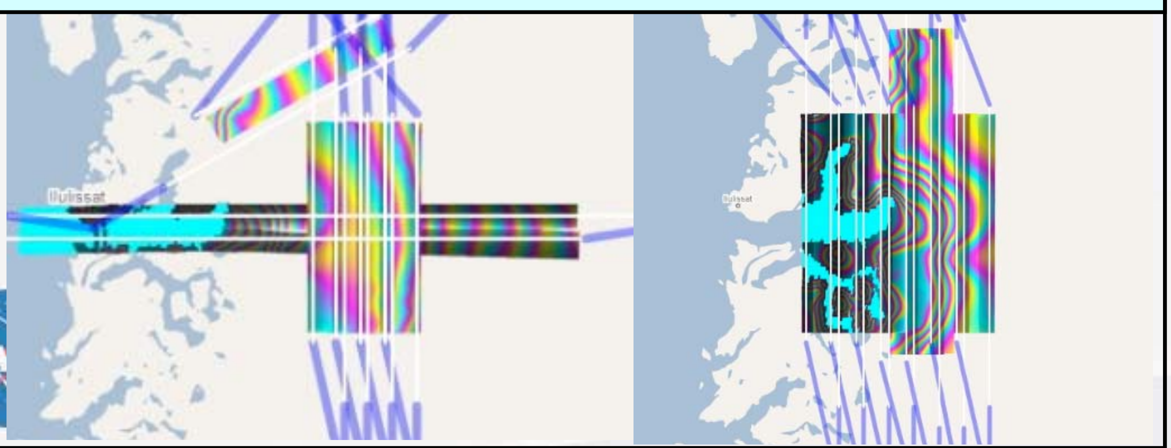
5/5/09 ATM flight path (left) to coincide with GLISTIN **5/4/09** & **5/5/09**



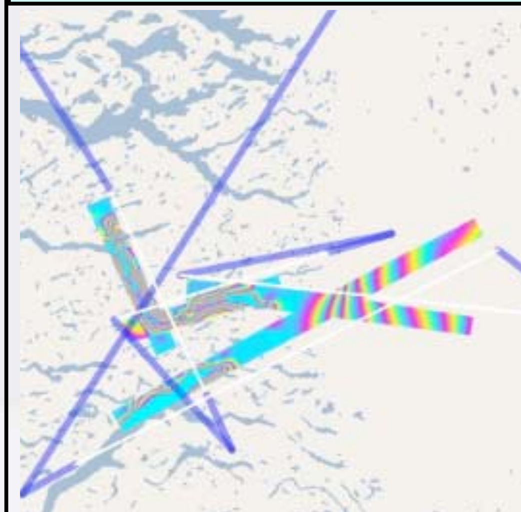


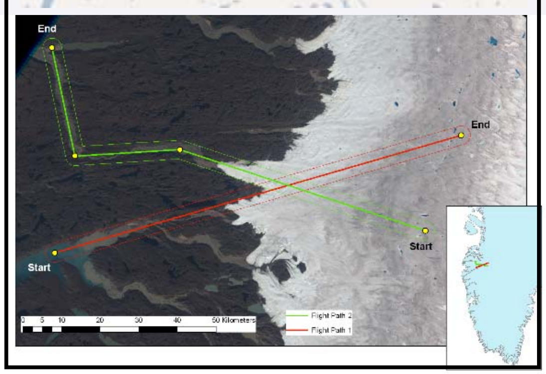
Two calibration sites at Summit and Swiss Camp. Ground (snow) data collected at Swiss Camp. Comparison with ATM will reveal penetration depth of Ka-band

5/5/09 & 5/6/09 mapping over Jakobshavn took place on consecutive days. Flights were repeated six days later **(5/11/09 & 5/12/09**). The ATM flew this region ~1 week prior

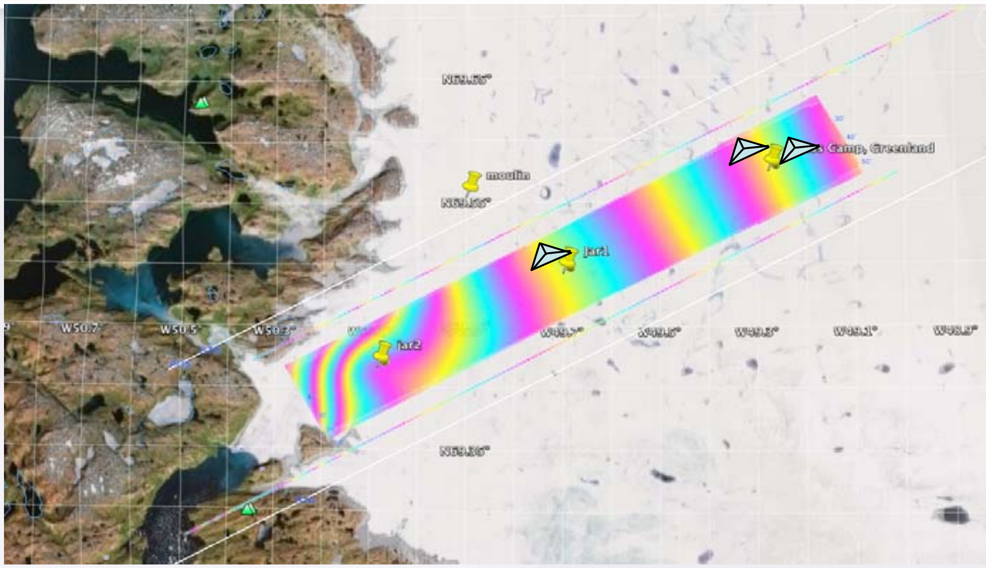


5/7/09 Watson River Glacial lake outlet. Mapping bathymetry and transition onto glacier. Glaciology and hydrology interests and ground activities





Calibration Sites: Swiss Camp and Summit



Summit science techs deploying and surveying a radar reflector.

- Swiss Camp line was flown at a heading of 61°.
- Reflectors were placed as above and surveyed by Koni Steffen (CIRES).
  - A JAR2 placement was originally planned but access was not possible by snowmobile).
- Ground measurements to include snow wetness, density and grain size

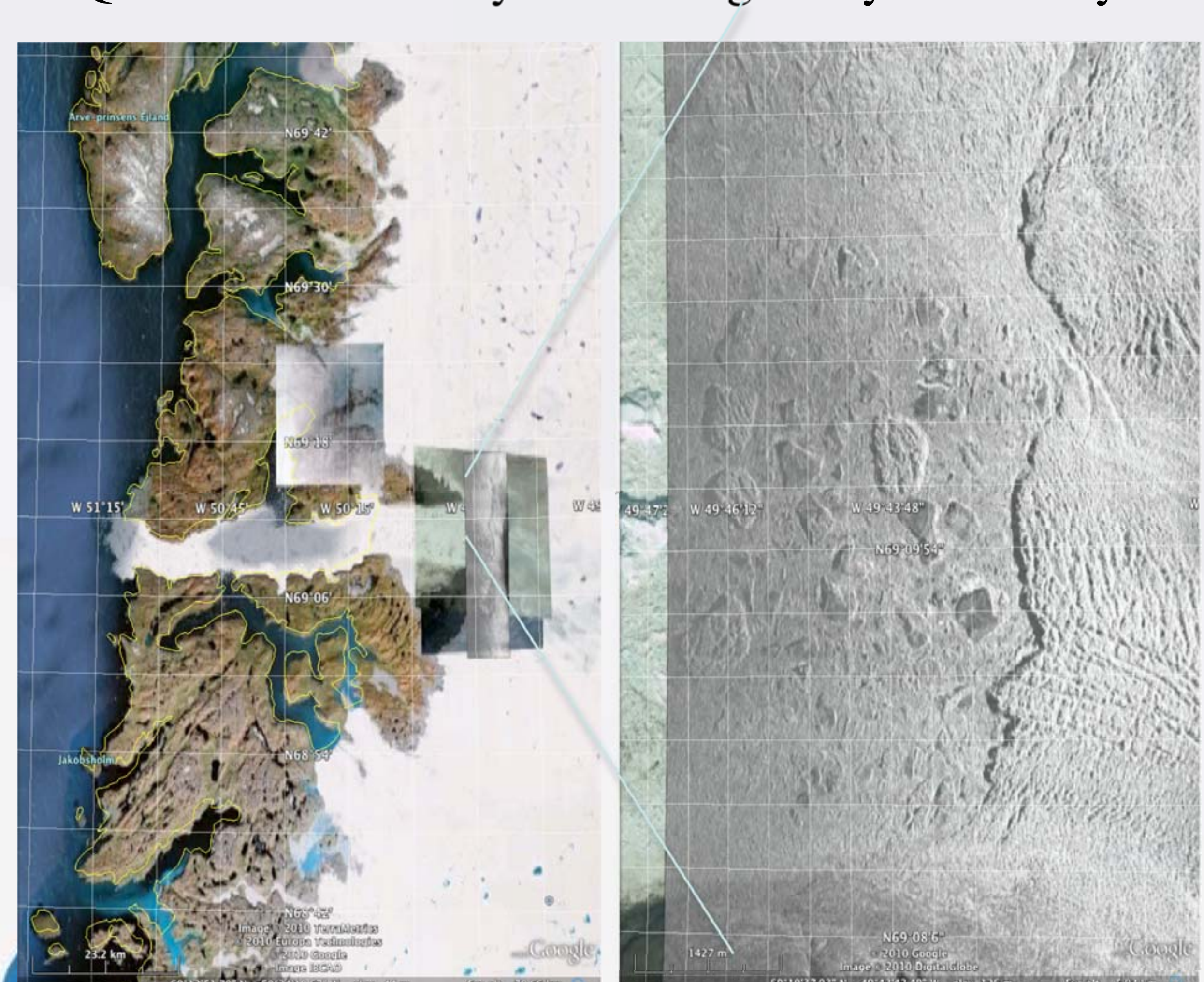
• Airborne overflights using GLISTIN-A on the GIII and the ATM lidar on a NASA P3 occurred May 4 and 5 of 2009.

• Summit overflight and ground data are key for calibration and validation of the radar data.

• Corner reflectors were placed about the ICESat calibration track and precision surveyed for 3D location.

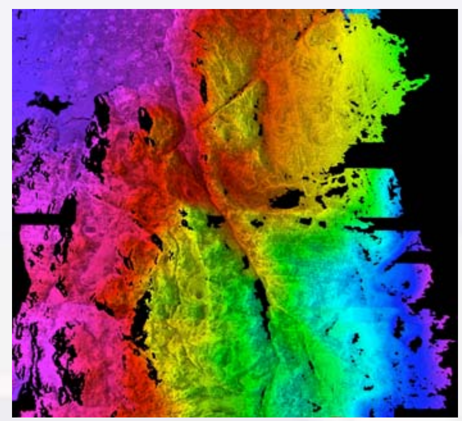
Jacobshavn Glacier Ka-band Imagery

Quick Look Intensity Processing: May 6 and May 12 – Jakobsholm Pass



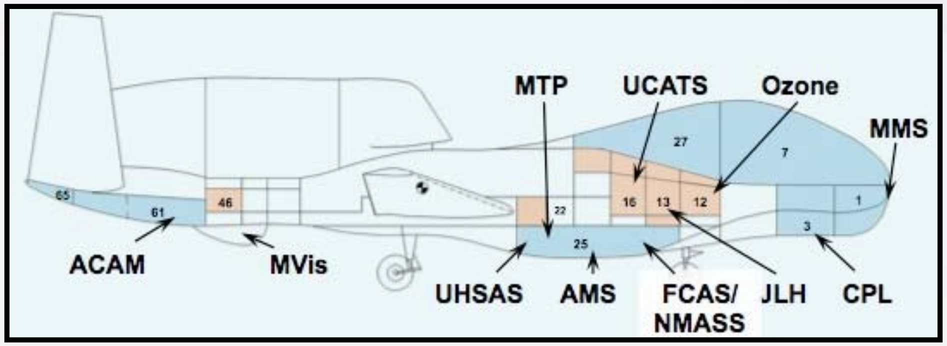
8 km

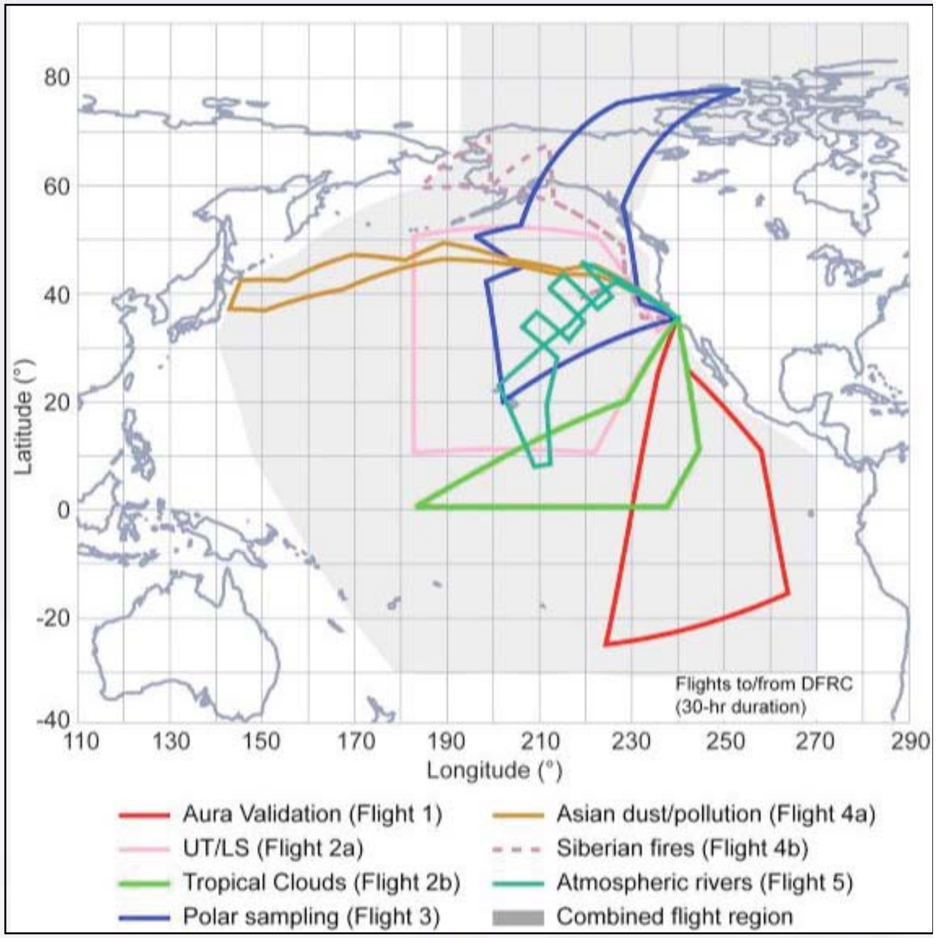
- Left shows Google Earth view zoomed out to show surrounding region. Quick look processing image is also shown in Google Earth.
- Right images are zoomed in to shown more details in the quick look processing (intensity only) of Jakobsholm pass. They have been imported into Google Earth.
- From the 6th to the 12th (toggle between) the ice sheet retreats ~ 1 km.



Elevation map 800 m Color Wrap

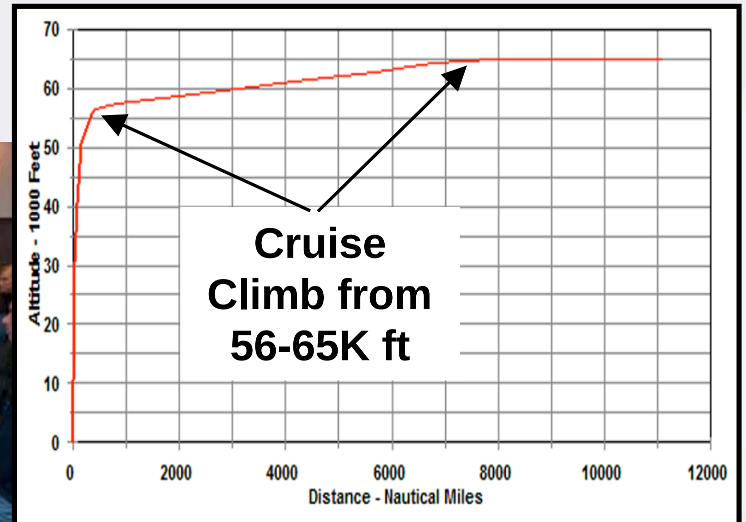
Global Hawk GLOPAC Mission





Global Hawk and Operations Center

Endurance	> 30 hours
Range	>11,000 nmi
Service Ceiling	65,000 ft
Airspeed (55K+ ft)	335 KTAS
Payload	1,000-1,500 lb
Length	44 ft
Wingspan	116 ft



Pilot control

Experimenter control

3rd GloPac Science Flight, April 23-24

Objective: fly to 85N, sample polar vortex, sample Asian dust.

Cloud Physics Lidar (CPL) on Global Hawk

PI Team

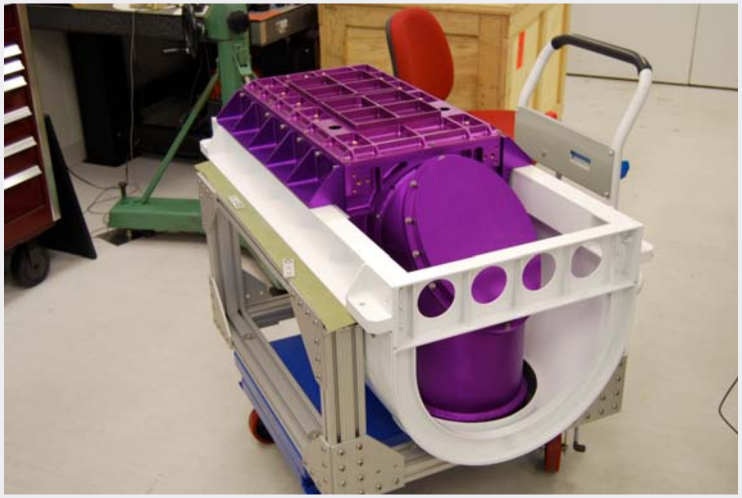
- Matt McGill, GSFC
- DFRC
- Northrop Grumman

Mission:

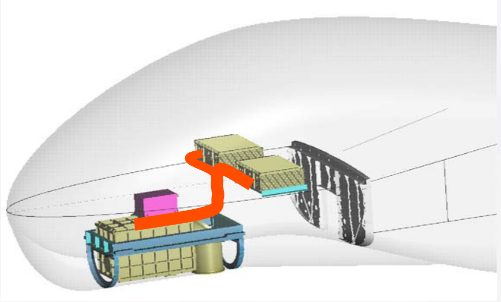
Lidar Measurement from a UAV Platform in Support of IPY Activities

CPL Detects:

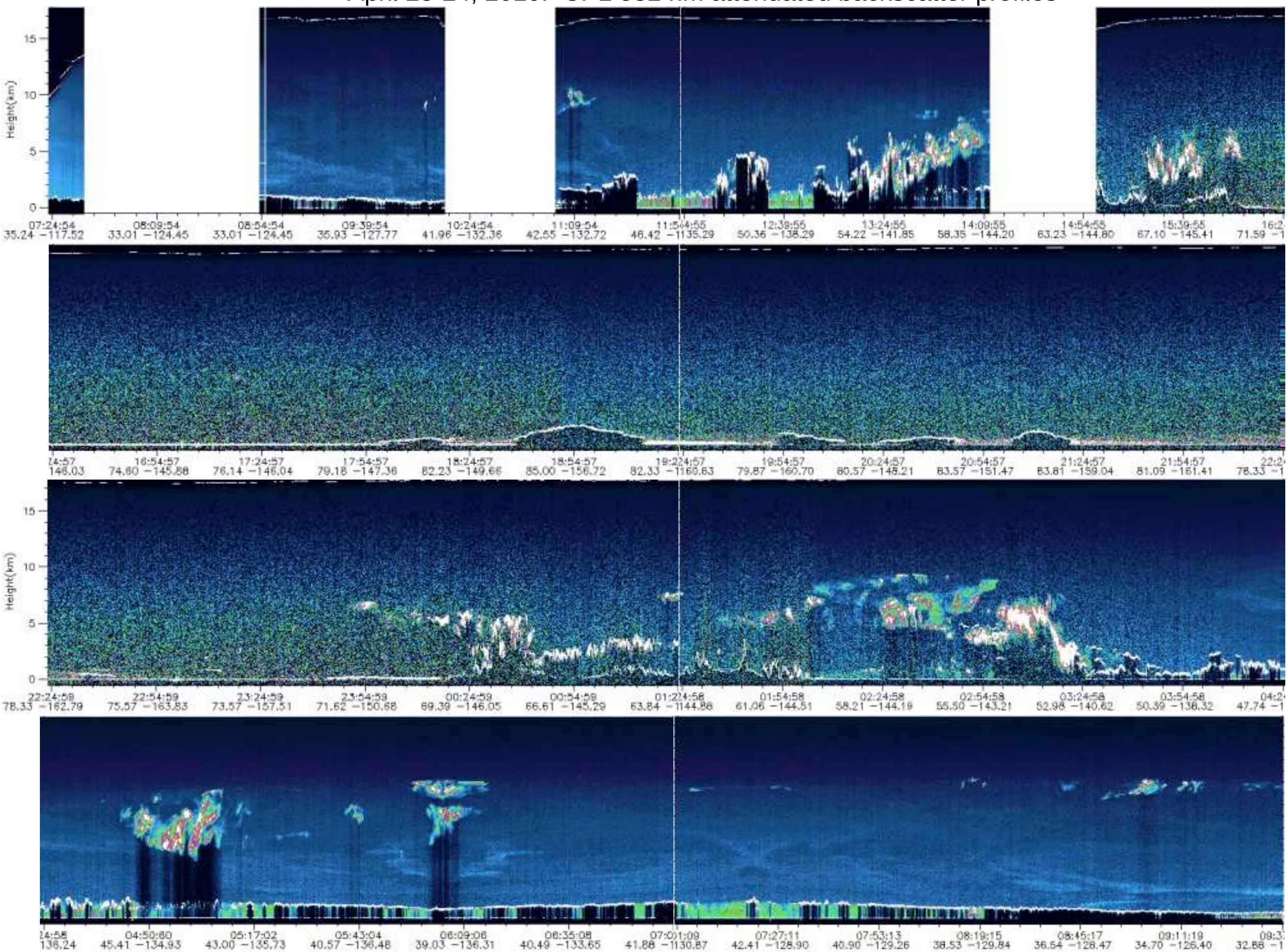
Cirrus
Stratus
Marine layer
Dust
Smoke



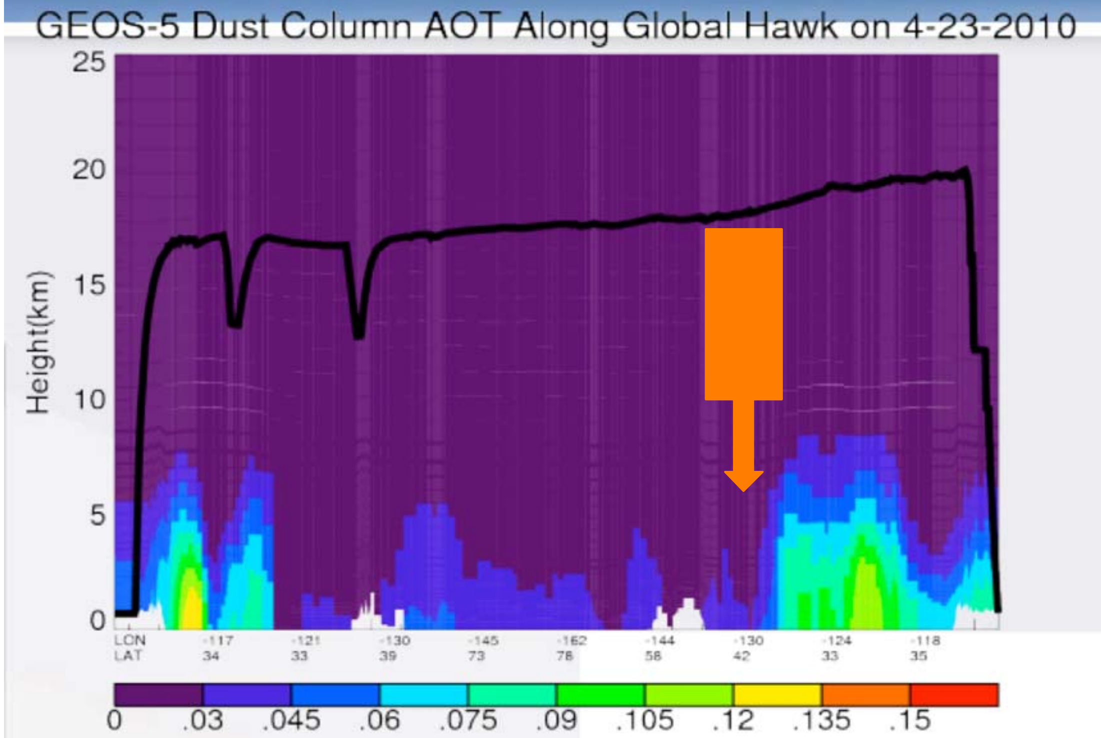
CPL instrument housing in the completed CPL carrier assembly. Also shown in is the handling/lifting cart that will be used to transport the instrument and raise it into the GH compartment.



April 23-24, 2010: CPL 532 nm attenuated backscatter profiles

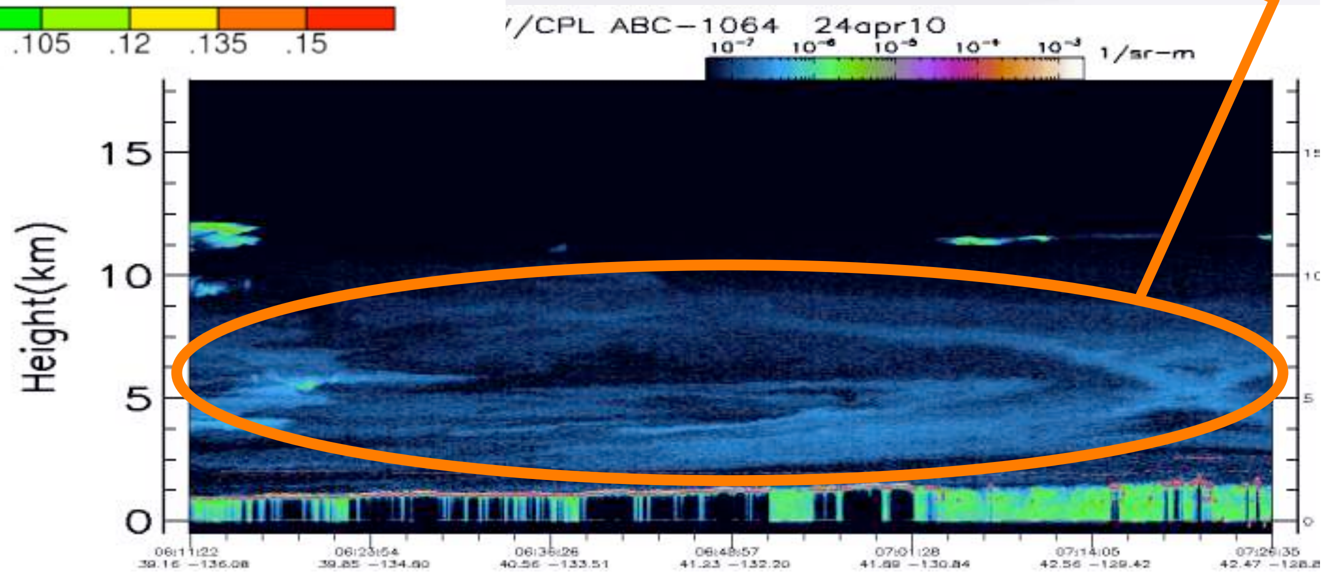


GEOS-5 model comparison with CPL



GEOS-5 model prediction of dust optical depth is ~0.04 in the comparison region

Average CPL-derived dust optical depth is 0.04



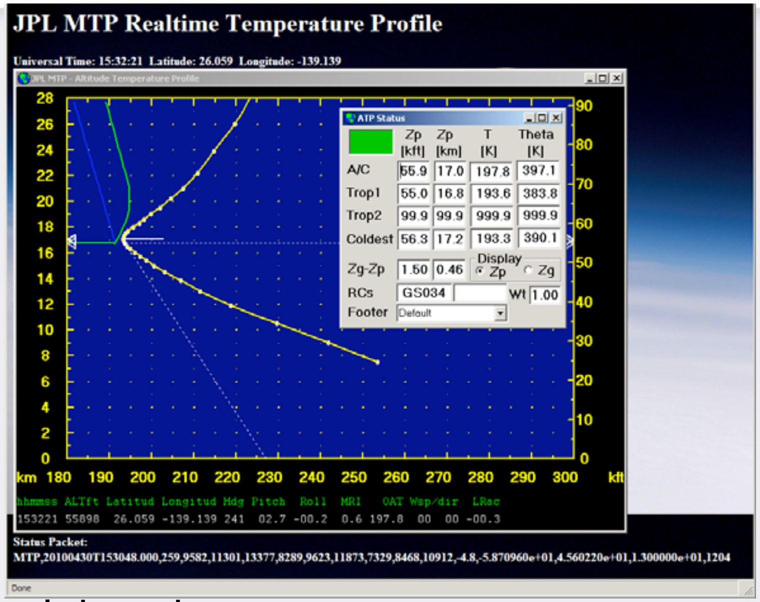
Airborne Microwave Temperature Profiler (MTP) on GH

PI Team:

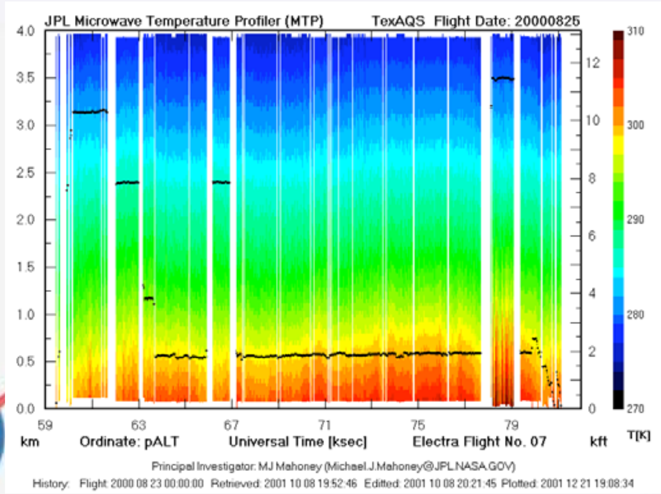
- MJ Mahoney, JPL
- DFRC

Approach / Mission:

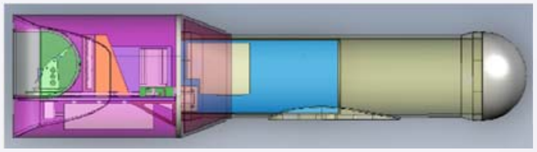
- Use microwave temperature profiler (MTP) observations to provide meteorological context for other airborne measurements, to allow atmospheric dynamics studies, and to provide satellite validation (Aura/Aqua)
- Build a copy of the GV MTP to integrate on the Global Hawk (GH)



MTP real-time data



MTP:

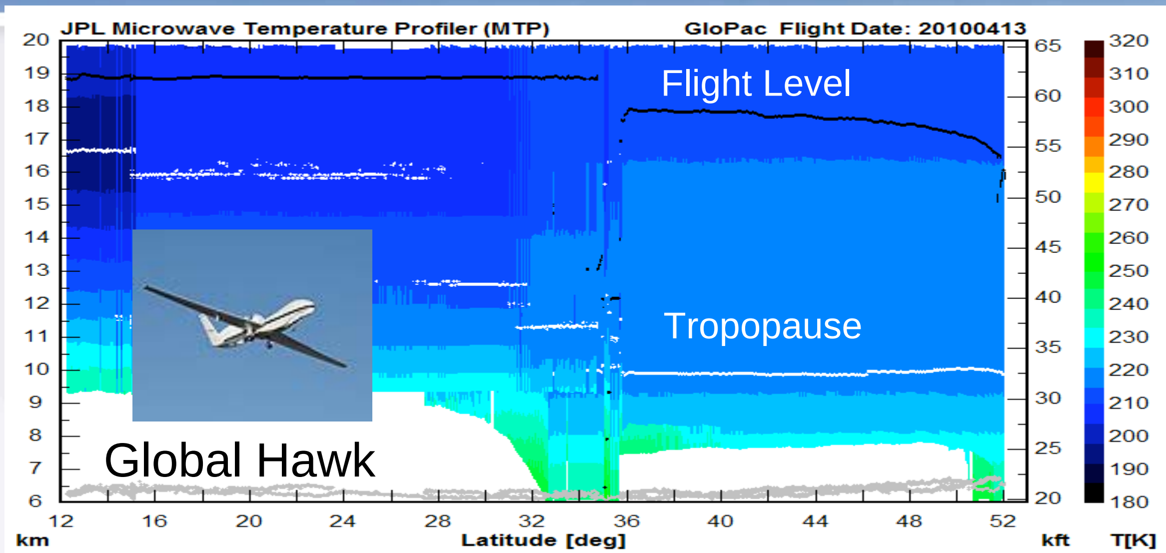


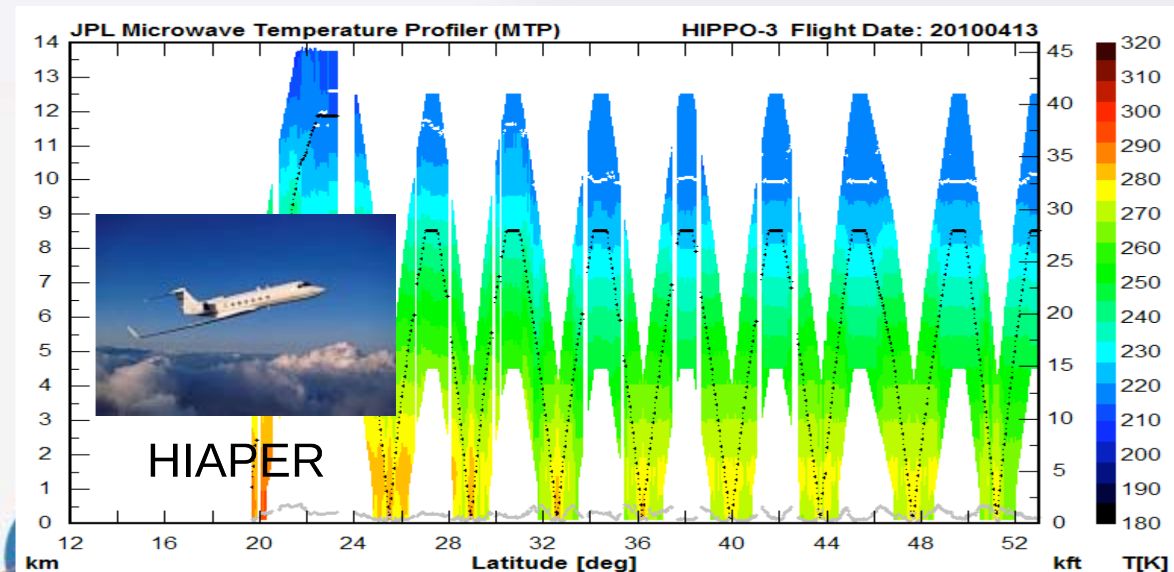
Over 30 years the JPL MTPs have participated in 47 field campaigns and accumulated 4353 flight hours on 752 flights

Microwave Temperature Profiler (MTP)

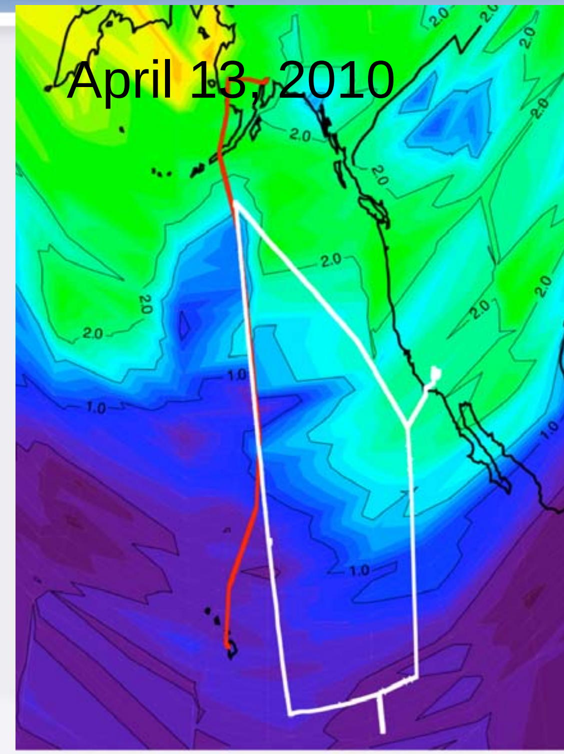
- Began at JPL >30 years ago
- Only group in the world to do airborne temperature profiling
- Initially used to study CAT
- Now used to provide meteorological context for trace gas and aerosol measurements made by other instruments, and to study atmospheric dynamics
- Global Hawk used the same MTP as the ER-2, WB-57F, and Geophysica, but had new Linux-based communication computer
- Campaigns: 53
- Flights: 824 (4696 flight hours)

Global Hawk and HIAPER MTPs





(Preliminary data)

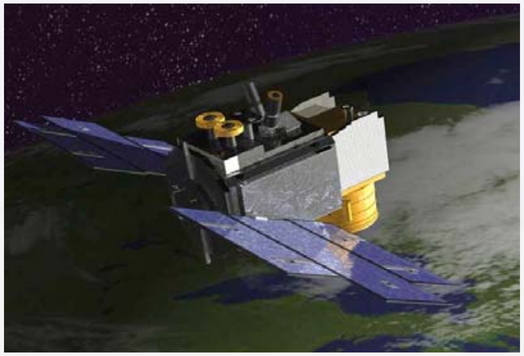


MLS ozone figure courtesy of Karen Rosenlof (NOAA)

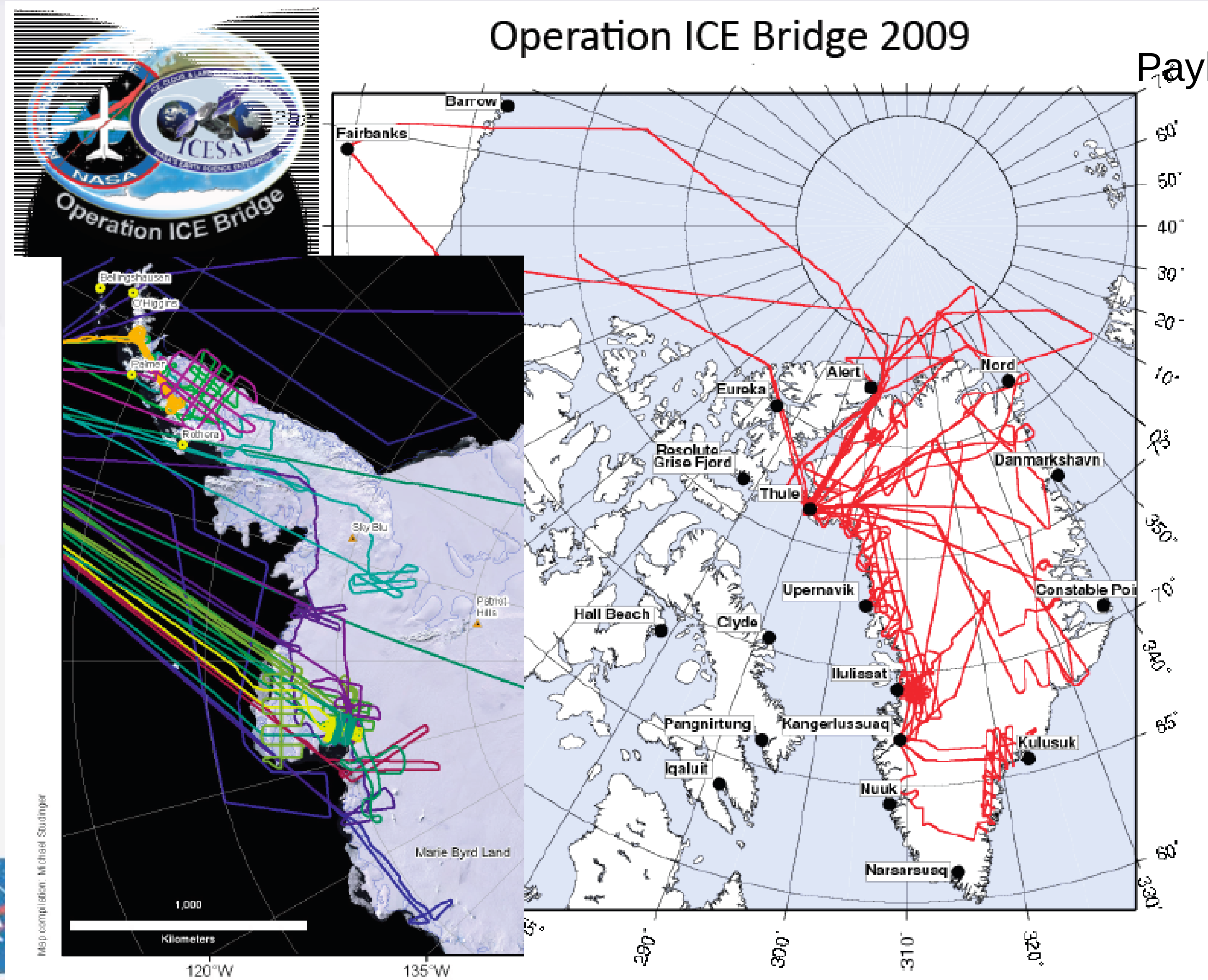
- Global Hawk and HIAPER flew over-lapping flight track on 2010-04-13 along Aura ground track.
- This will allow inter-comparisons to be made.

Other NASA Activities

- Operation ICE Bridge
- SAR will move to UAV (Global Hawk)
- SIERRA activities with SAR
- Earth Venture arctic carbon science
- UAS Issues: Basing, telemetry, airspace



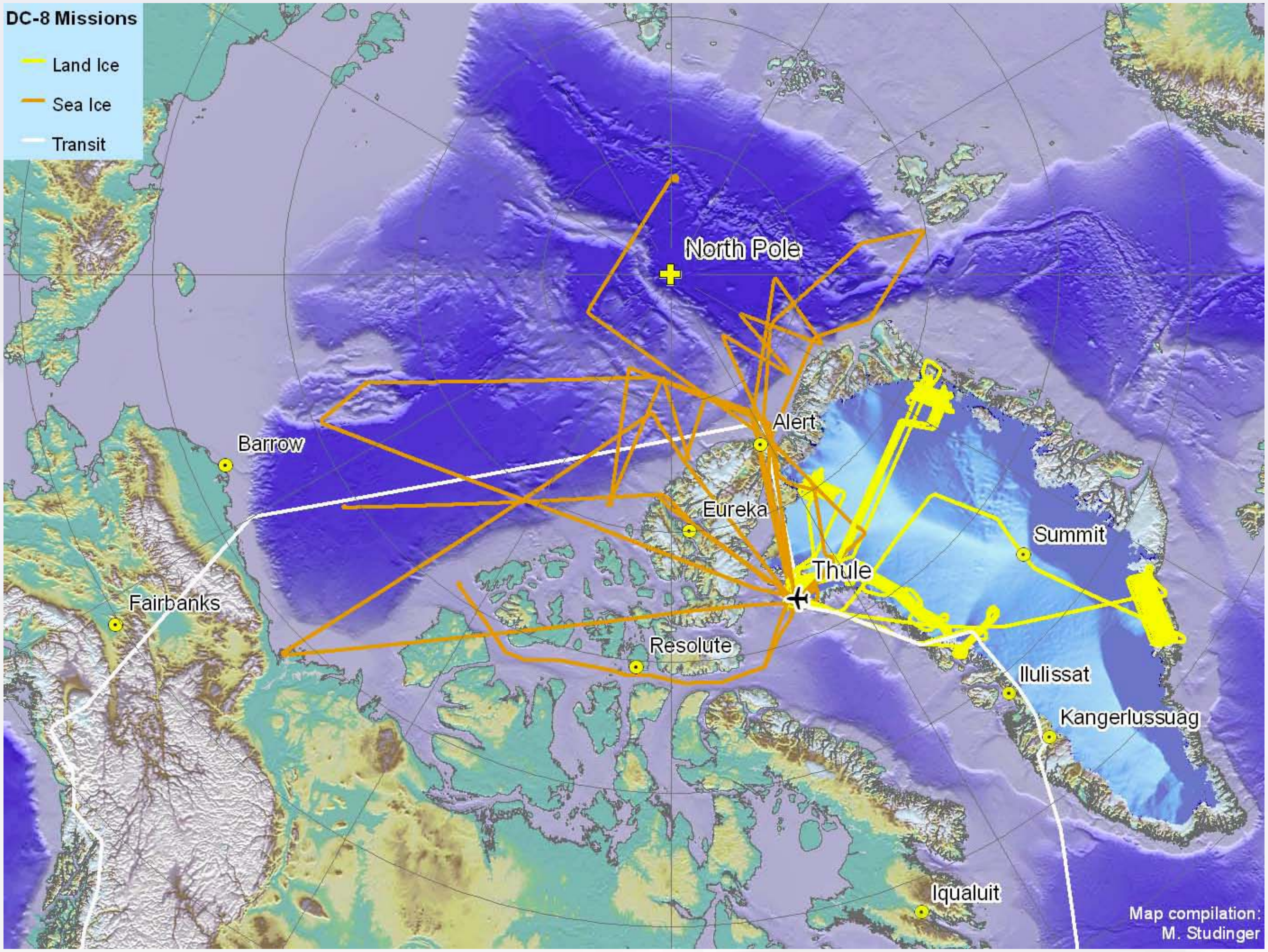
Operation Ice Bridge: ICESAT Gap-filler



Payload Instruments

- ATM
- GPS
- PARIS
- SAR
- LVIS

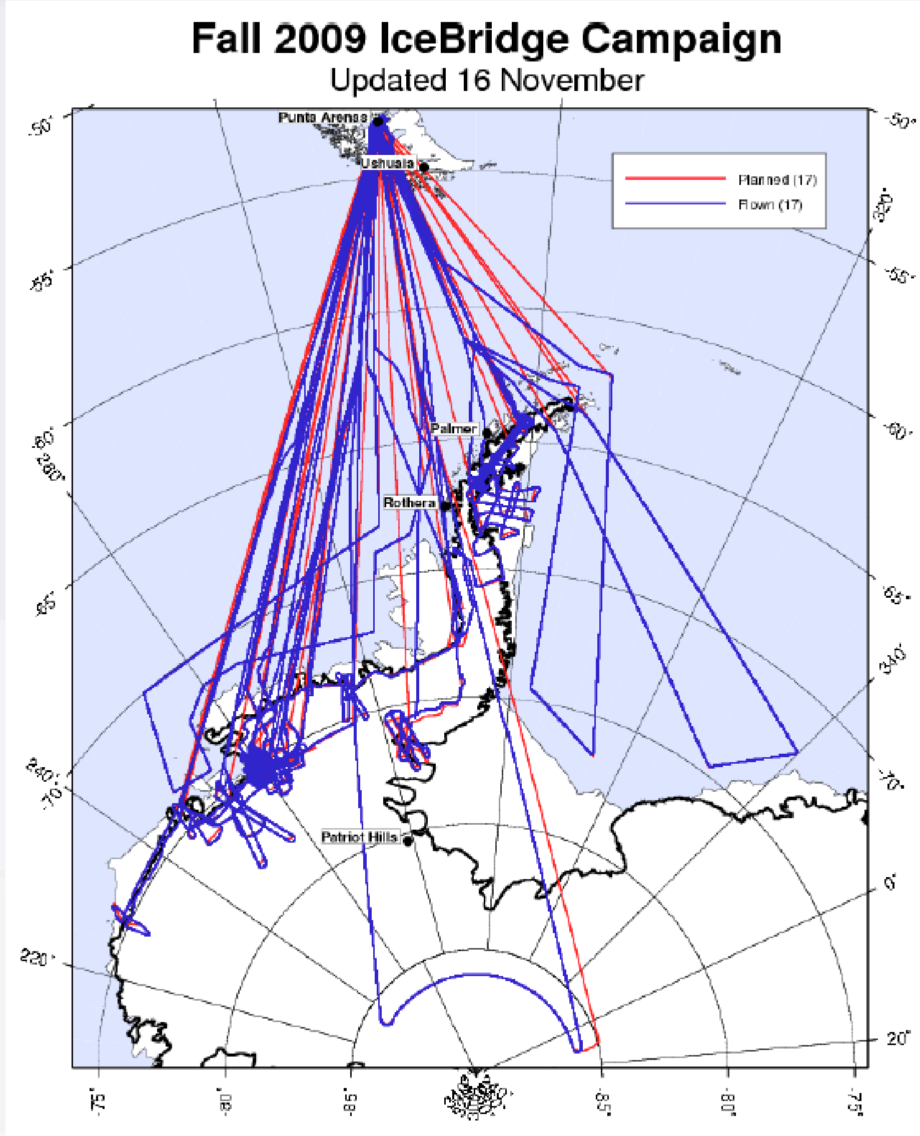
Operation Ice Bridge: Spring 2010



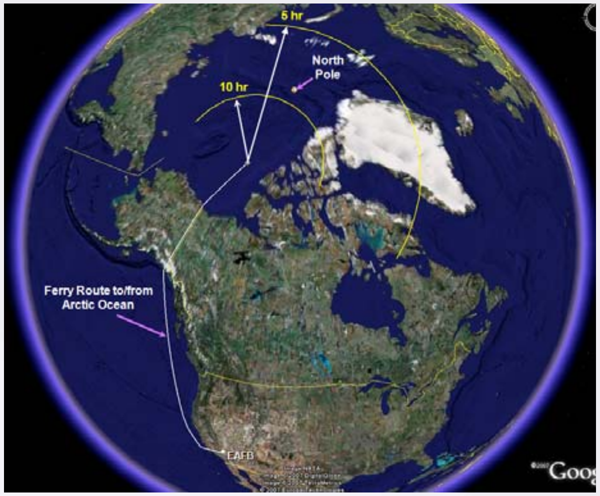
Operation Ice Bridge: Antarctic Mission

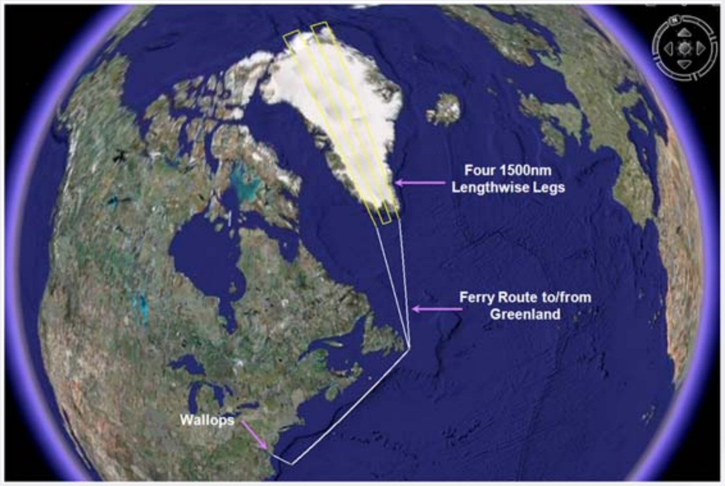
Pine Island, Thwaites,
Smith& Kohler glaciers

P-3 with 5 instruments
DC-8 with 5 instruments



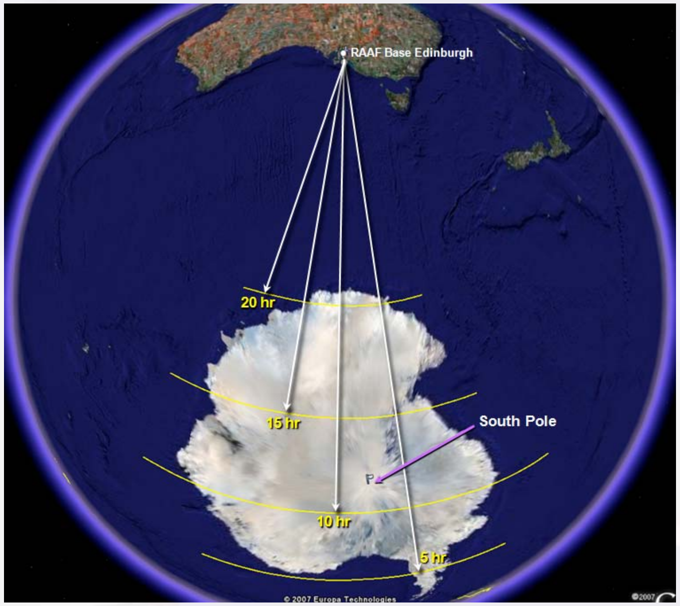
Upcoming Global Hawk Coverage - Arctic, Greenland and Antarctica





- Proven deployment Sites
  - Pax River
  - Australia
  - Germany

- New Deployment Sites
  - Wallops
  - Punta Arenas
  - Alaska



- UAVSAR pod and system duplicated for GH
- First flights 2011
- Continues to Operation Ice Bridge by 2014

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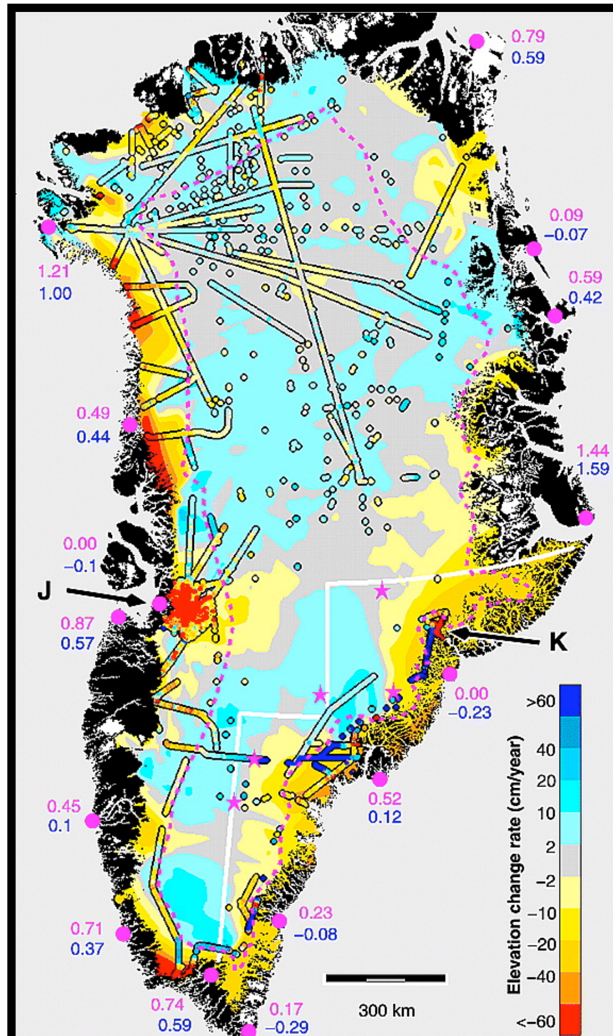
Scientific Motivation For Mapping Sea Ice and Ice Surface Topography

- Ice sheets and glaciers contribute 50% of the observed global sea level rise.
- Measuring changes in ice sheet and glaciers topography is an important scientific and societal priority.



Greenland

Thinning of coastal regions (0-25 m/yr) dominates thickening of the interior (10-30 cm/yr).

Antarctica

- Coastal thinning (0-6 m/yr) dominates the mass balance of the ice sheet.
- Changes in interior elevation reflect decadal variations in snowfall.

Science requirements cover two regimes: glaciers & ice sheets

- Glaciers: 100 m horizontal scale with 1 m vertical accuracy.
- Ice sheets: 1 km horizontal scale with 10 cm vertical accuracy.
- Comprehensive and frequent (seasonal) coverage required for both, especially coastal sectors.

from airborne laser altimetry (Krabill et.al.)